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Effect of different fluid therapies on postoperative pulmonary complications in neurosurgical patients

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Abstract
Effective fluid management is a crucial aspect of perioperative treatment for patients having neurosurgery. The basic objective of fluid management in neurosurgery is to maintain normal blood volume and avoid a decrease in serum osmolarity. In order to maintain a normal blood volume, it is crucial to deliver fluids in the correct quantities using acceptable techniques. Additionally, to avoid a drop in the concentration of solutes in the blood, the selection of the fluid is of greatest significance. The perioperative phase is subject to significant controversy on the selection and ideal quantities of fluids to be supplied. Neurosurgery employs six fundamental body positions: supine, lateral, prone, concorde, seated, and three-quarters. Moreover, changes in body posture, whether in conscious or anesthetized individuals, result in notable modifications in the circulatory and respiratory systems. These alterations might impact the process of exchanging gases in the blood and the circulation of blood in the brain.

Keywords: Neurosurgical patients, fluid therapies, pulmonary complications

Introduction

Fluid management is an integral component of fundamental care in several therapeutic scenarios. Fluid treatment during the perioperative period in patients having neurosurgery is an essential aspect of anesthetic management and critical care [1]. The primary objective of fluid management in neurosurgical anesthesia is to avoid cerebral injury resulting from insufficient cerebral perfusion and to provide an optimal operative setting. Hence, it is essential to preserve hemodynamic stability and provide adequate cerebral perfusion pressure during neurosurgical procedures [2].

Hemodynamic changes and disturbances in electrolyte levels often arise during neurosurgery due to the frequent use of diuretic medications to alleviate elevated intracranial pressure and swelling. Furthermore, the administration of substantial quantities of fluids may be necessary, depending on the nature of the operation, to address preoperative hypovolemia and perioperative unstable hemodynamics, as well as to avoid cerebral vasospasm [2].

Neurosurgery involves managing patients by ensuring the stability of their internal environment, particularly by maintaining a balanced blood flow to the brain and providing sufficient oxygen supply. This is achieved by concentrating on factors such as hemodynamic stability, cerebral perfusion pressures (CPP), and cerebral blood flow. Hence, it is crucial to prevent hypovolemia and the sedative impact of anesthetics in order to avert neurological harm. Another risk factor to consider is the placement of the patient, particularly when they are in a seated or prone position. These positions may lead to hemodynamic alterations, such as venous pooling and reduced venous return to the heart [3].

Postoperative pulmonary complications (PPCs) are common, serious, and often potentially preventable. The most common PPCs are pneumonia, acute lung injury, pulmonary edema and acute respiratory distress syndrome [3].

Choice of fluids in neurosurgical patients

During the perioperative stage of neurosurgeries, it is recommended to use balanced crystalloids as suitable solutions [4]. Crystalloids, namely 0.9% normal saline, are often used as the first treatment option because to their slightly higher osmolality (308 mOsm/L). This property may aid in reducing the probability of brain swelling.

While there is no definitive prohibition, it is important to be cautious while using colloids, namely hydroxyethyl starch [5]. Nevertheless, Thy *et al.*'s meta-analysis determined that the well-known negative effects of colloids, such as kidney damage and blood clotting disorders, did not exist when they were administered perioperatively in noncardiac procedures [6].

Types of fluid

Intravenous solutions may possess isotonic, hypotonic, or hypertonic properties. Typically, isotonic solutions are used for the treatment of a decrease in the amount of fluid outside of cells (Extracellular fluid depletion). Hypotonic solutions are used to replenish both extracellular fluid and fluid within cells (Intracellular fluid) that has been lost. Hypertonic solutions are utilized to correct symptomatic low levels of sodium in the blood (Hyponatremia). Hypertonic saline is often used in trauma scenarios due to its ability to reduce intracranial pressure in individuals with head injuries and those recovering from burns [7].

Crystalloids	Colloids
Dextrose in water (D5W) (2.5%, 5%, 10%)	Albumin (5%, 25%)
Sodium chloride (NaCl) is available in various concentrations: 0.225%, 0.33%, 0.45%, 0.9%, 3%, 5%, and 7.5%.	Starches (Hetastarch 5%, pentastarch 10%)
Ringer's lactate	Dextrans 40 and 70
Plasmalyte A	Hematological products (Whole blood, erythrocyte concentrates, cryoprecipitate, platelets, fresh frozen plasma, blood replacements or synthetic blood)

Strategies of perioperative fluid therapy

Liberal fluid therapy

In the last two decades, the most effective method of intravenous fluid administration has changed due to advancements in surgical methods, patient routes like Enhanced Recovery after Surgery, growing scientific research, and prevailing norms. Minimally invasive techniques, including the use of robotics, have decreased the amount of fluid loss and physical manipulation of organs during various surgical procedures [8].

Restrictive ('zero balance') intravenous fluid therapy

In recent years, the concept of "restrictive fluid management" has been more popular, especially with the broad implementation of Enhanced Recovery after Surgery pathways. Recent recommendations have recommended a restrictive approach [9].

Goal-directed fluid therapy

In order to get the ideal fluid volume status, it is crucial to prevent excessive fluid intake and excessive limitation, and instead, create personalized fluid regimens based on objective criteria. It is important to focus on these specific characteristics before surgery and then measure them throughout the surgery. GDFT is a method of fluid administration that aims to achieve specific objectives by directly measuring hemodynamic parameters, including cardiac output, stroke volume, stroke volume fluctuation, pulse pressure variation, systolic pressure variation, pleth variability index (PVI), and other variables [10].

Post-operative Pulmonary complications (PPC) of fluid therapy

PPC, include a range of respiratory issues that may occur after surgery, including pneumonia, the need for invasive mechanical ventilation, and severe hypoxemic respiratory failure. Excluding complications such laryngospasm, which occur in the airway during or immediately after surgery and anesthesia, are often not accounted for [11].

Effect

The development of a PPC is linked to longer hospital stays and higher healthcare expenses. Moreover, an increase in the number of PPCs leads to a corresponding increase in both the length of stay and the likelihood of early death. The intensity and effect of PPCs might vary. Patients acquiring pneumonia that causes respiratory failure needing invasive mechanical ventilation will have a considerably bigger effect on recovery following surgery than if they had merely had simple pneumonia. Individuals who have PPC tend to have more unfavorable long-term outcomes [12].

Causes and pathophysiology

The correlation between recent administration of anesthesia and surgery and the emergence of a novel lung ailment exemplifies the detrimental impact of anesthesia and surgery on the respiratory system. These negative consequences may be directly linked to a fraction of all potential lung diseases based on their underlying physiological mechanisms. Individuals who have many medical conditions are more likely to have PPC, and the severity of these complications is greatly affected by their health status prior to the sickness [13].

1. **Pneumonia:** Postoperative pneumonia is more common in patients who have preexisting conditions and functional impairments [14].
2. **Pulmonary Inflammation:** When the lung is directly injured or when there is a severe systemic infection, inflammation may occur. This inflammation can cause damage to the alveolocapillary membrane, resulting in the leakage of fluid rich in proteins into the alveolar space [13].
3. **Atelectasis, sputum retention, and loss of airway Patency:** Lung regions that get blood flow but lack air exchange result in a V/Q mismatch, which presents as compromised oxygenation. Collapsed lung regions exhibit lower compliance compared to aerated lung areas, resulting in a higher workload for breathing. This increased workload may lead to symptoms such as shortness of breath or rapid breathing (tachypnea) [15].

Surgical positions in neurosurgery and its effect on hemodynamics

Proper patient placement is a vital aspect of neurosurgical procedures, and it is the joint duty of the neurosurgeon and the anesthesiologist. The primary principles for proper posture include ensuring patient safety, optimizing surgeon comfort, promoting venous drainage to reduce brain tension, using gravity to keep the lesion exposed, and employing dynamic retraction. Silicone cushioning is necessary to protect any skeletal prominences. The positioning of the head may be achieved by the use of a horseshoe headrest or three pin skull clamps, according to the following fundamental guidelines: refraining from lifting the head above the heart by more than 30 degrees, preventing excessive rotation of the head to one side beyond 30 degrees, and ensuring a gap of 2 to 3 finger widths between the chin and sternum. Failure to place the patient correctly during surgery might lead to significant difficulties. Therefore, utmost caution must be used throughout this stage of the surgical procedure [16].

There are six basic body positions utilized in neurosurgery

The positions mentioned include supine, lateral, prone, concorde, sitting, and three-quarters. Moreover, changes in body posture, whether in conscious or anesthetized individuals, lead to notable modifications in the circulatory and respiratory systems. These modifications might impact the process of exchanging gases in the circulation and the flow of blood in the brain [17].

Prone Position [17]

Fig 1: Prone positioning in neurosurgery [18]

Approaches to the posterior fossa, suboccipital area, and spine are often performed in the prone position.

Benefits: The posterior methods are well-suited for this posture, and there is a reduced occurrence of venous air embolism in comparison to the Sitting position.

Risks: Logistically, this configuration presents the most challenging aspects in terms of delivering sufficient oxygenation, ventilation, hemodynamic stability, and the secure placement of intravenous lines and the tracheal tube. The patients' airway has limited accessibility. Possible complications include pressure ulcers, vascular compression, brachial plexus injury, air embolism, visual impairment, and quadriplegia [17].

Hemodynamics and Ventilation

Transitioning the patient from a supine to a prone posture results in elevated intraabdominal pressure, reduced venous blood flow back to the heart, and heightened systemic and pulmonary vascular resistance. Head-up tilt or kneeling with flexible lower limbs leads to the accumulation of venous blood in the lower body, resulting in reduced venous return and the development of hypotension. While the cardiovascular effects of assuming a prone position have not been well described, evidence indicates that there may be a drop in left-ventricular ejection fraction and cardiac index, which might lead to hemodynamic instability. Prone placement may enhance oxygenation and oxygen delivery by improving the alignment between ventilation and perfusion [19].

Sitting Position [17]

This posture is primarily used for performing surgeries on the posterior fossa and cervical laminectomy.

Benefits

The advantages of this posture for posterior fossa surgery include less bleeding, better cerebral venous drainage, less tissue retraction, and lower chances of cranial nerve injury. It is possible for the anesthesiologist to reach the patient's airway.

Fig 2: Sitting position in neurosurgery [18]

Risks: Manipulations in the brain stem might potentially lead to VAE (venous air embolism), paradoxical air embolism, bradycardia, or cardiac collapse. Furthermore, instances of macroglossia, blockage of the upper airway, pneumocephalus, subdural hemorrhage, and quadriplegia have been recorded.

Hemodynamics and Ventilation

Approximately one-third of patients have postural hypotension while in the traditional sitting posture, with 2-5% of patients experiencing severe hypotension characterized by a fall in blood pressure of more than 50% from their baseline.

The primary hemodynamic effect is a reduction in venous return, resulting in a drop in cardiac output and low blood pressure [17].

Thus, hemodynamic instability and heart illness are considered to be relative contraindications for assuming a sitting posture. Application of elastic bandages around the legs is essential to avoid the accumulation of blood in the lower limbs and should be done in all instances. The sitting posture enhances ventilation relative to the supine position by causing the diaphragm to go downward. This reduces pressure in the abdomen, leading to enhanced ventilation in the lower areas of the lungs and a reduction in ventilation-perfusion mismatch [17].

Supine Position [17]

The supine position is often used for a variety of neurosurgery procedures, such as cranial surgeries, carotid endarterectomies, and anterior approaches to the cervical and lumbar spine [17].

Benefits: This position is considered the most basic since it does not need any specialized equipment and can be readily attained.

Risks: Optimal surgical circumstances are often achieved by rotating or flexing the head.

Neurosurgery employs three distinct supine posture techniques. The horizontal posture is attained when the patient is reclining on a flat surface, facing upwards. To avoid skin-to-metal contact, it is necessary to use padding or restraints to keep the arms either close to the body or positioned on arm boards. It is recommended to provide padding for the bony contact sites located at the elbows and heels. The lawn chair position is a variant of the horizontal position, characterized by a 15-degree angulation and flexion at the trunk-thigh-knee. This posture offers a more anatomically correct alignment of the lumbar spine, hips, and knees. To maintain flexion, one might position a blanket, cushion, or pillow under the knees. Another benefit of the lawn chair posture is that it provides a little increase in head elevation, which helps improve the flow of blood from the brain. Additionally, it also offers a tiny elevation of the legs, which may enhance the return of blood to the heart. The head-up tilt or reverse Trendelenburg maneuver typically entails adjusting the body posture by 10–15 degrees above the horizontal axis in order to provide adequate venous drainage from the brain.

Ventilation and Hemodynamics

The link between alterations in vertical elevation and average arterial pressure is such that a 2.5 cm modification in height from the heart's baseline leads to a 2 mmHg displacement in the opposite direction. Furthermore, the venous compartment functions under reduced pressure, and the body's position has an impact on the blood flow back to the heart. Head-down tilt improves blood flow from the lower limbs while concurrently worsening blood congestion in the upper body. When the head is inclined below the level of the heart, the venous pressure in the brain increases according to the hydrostatic pressure differential. After undergoing short surgical procedures, patients may have postoperative headache, as well as congestion of the conjunctivae and nasal mucosa. To optimize cerebral blood flow, it is advisable to raise the head above the level of the heart by using the reverse Trendelenburg position or by adjusting the table to a flexed position. The head may typically be safely rotated at an angle of 45 degrees relative to the body. Nevertheless, if more rotation is necessary, it is recommended to use a roll or cushion to provide support to the shoulder on the other side [17].

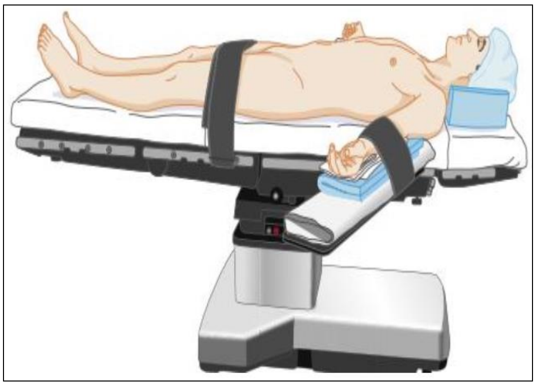

Fig 3: Supine position [18]

Lateral Position [17]

Patient Surgical procedures requiring the temporal lobe craniotomy, skull base, posterior fossa, or retroperitoneal access to the thoracolumbar spine, need a lateral surgical approach.ts undergoing operations involving the temporal lobe craniotomy, skull base, or posterior fossa, or a retroperitoneal approach to the thoracolumbar spine, are surgically approached from the lateral position.

Benefits: The temporal lobe is best approached during surgery when the patient is in this posture.

Risks: Potential complications include pressure palsies, brachial plexus injuries, stretch injuries, and ventilation-perfusion mismatch.

Hemodynamics and Ventilation

Gravitational alterations in the ventilation-perfusion connection in the lung occur as a result of lateral displacement. The ventilation-perfusion mismatch is exacerbated when the dependent zones of the lungs are under positive pressure ventilation and the nondependent zones are under general anesthesia [17]. Because of the risk of brachial plexus damage and compression of the axillary arteries, the patient's dependent (lower) arm must be carefully positioned. Placing a low cushioned arm board between the table and the head fixator allows the dependent arm to be rested in either a hanging or ventral position. Another option is to use a cushion to support the forearm as you wrap towels over both the arm and the forearm. Abducting the shoulder and flexing the elbow are the correct positions. Avoiding arm ischemia, brachial plexus damage, and compartment syndrome may be achieved by placing an axillary roll, an inflated cushion, or a gel pad beneath the upper chest, rather than in the axilla itself.

Fig 4: Lateral decubitus position [18]

Conclusion

Patients undergoing neurosurgery in either the prone or sitting position benefited more from goal-directed fluid treatment than from restricted fluid therapy, which led to a shorter hospital stay and less time in the intensive care unit.

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